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CATALYST REACTOR FOR PROCESSING HAZARDOUS GAS USING NON-THERMAL PLASMA AND DIELECTRIC HEAT AND METHOD THEREOF

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a reactor and a method for processing a hazardous gas using a non-thermal plasma technology and a dielectric heat, and more particularly to a reactor and method for processing hazardous gas, capable of improving a removing rate of the hazardous gas and the selectivity of a reacting process using a dielectric heat produced by a non-thermal plasma and catalyst at a process of decomposing the hazardous gas.

Description of the Related Art

Generally, since volatile organic compounds (VOC) discharged from industries are substances causing photochemical smog to be happened in the atmosphere, as well as being harmful to human, several countries control and regulate the emission of contaminants into the atmosphere. Meanwhile, according to the United Nations Framework Convention on Climate Change, the regulation concerning the emission of perfluorocarbon (PFC) and chlorofluorocabon(CFC), which are substances causing the global climate to warm, has set stricter in stages. For example, the total amount of emission of these substances will be regulated from 2002 year. Accordingly, various technologies for decomposing compounds such as PEC and CFC have been investigated, including: incineration, catalysis, absorption or biological filtration. Unfortunately, many of these technologies are not able to efficiently satisfy the regulation concerning the emission of the hazardous gas. The technology using incineration and catalysis needs indispensably a high heat source, but such high heat source cannot be continuously maintained in industry such as a process of manufacturing a semiconductor device, in which the hazardous gas is intermittently discharged. In order to maintain the high heat source, high expensive cost is required.

Meanwhile, there is another technology for decomposing or oxidizing hazardous gas using non-thermal plasma, without using a high heat source. One example is disclosed in U.S. Pat. No. 5,236,672 issued to Nunez et al. According to the Nunez et al. patent, a non-thermal plasma consisting of electrons and ions is produced by applying an AC power of high voltage to a plasma reactor, in which dielectric or ferroelectric pellets or beads having a diameter of a few millimeters are

filled. The hazardous gas is decomposed with the chemical reaction due to the portion of energy produced in the reactor. However, such technology for decomposing the hazardous gas needs a high power cost. In addition, by-product of aerosol state, which is produced at the decomposing process, is attached to a surface of the electrode as well as packed materials, thereby interrupting the operation of the reactor or causing the reactor to be clogged. Therefore, there is a problem that such technology cannot be realized in practice.

In addition, similar to the Nunez et al. patent, reactive bed plasma air purification is disclosed in U.S. Pat. No. 4,954,320 issued to Birmingham et al, in which the reactor is filled with noble metal catalyst beads, alumina beads or absorbents, thereby absorbing with the non-thermal plasma or producing catalysis reaction. Also, U.S. Pat. No. 5,843,288 issued to Yamamoto discloses technology of coating transition group of metal catalyst, such as Pt, Pd, Co, Ni or the like, on a surface of a ferroelectric bead to reduce by-products of gas state produced in the reactor and the alternating current power unit disclosed in the above patents.

As described above, the reactor for processing hazardous gas using non-thermal plasma includes a tubular body, in which dielectric pellets or beads are filled. In case of using the catalysis process together with the plasma, the dielectric pellets or beads are coated with a catalyst. However, if the above technologies are employed in a process of discharging the hazardous gas in practice, the pressure loss is happened due to the packed dielectric material in the reactor. Also, particulate materials contained in the discharged gas would lead the reactor to be clogged. In addition, if such a reactor is employed in an engine for a transport, which generates a vibration inevitably, interfaces of pellets or beads may be clacked. Furthermore, since a number of tubular reactors must be provided in a bundle in order to process a large volume of discharged gas, there is a problem that the size of the entire system is huge.

In particular, if the volume or capacity of the reactor is increased, the utility thereof is problematic, and the dielectric heat produced by the alternating current is not concentrated into a reacting space. Therefore, since the performance of the catalyst activated by the heat does not come up to expectations, the energy efficiency of the entire processes is significantly reduced.

The process utilizing both the non-thermal plasma and the catalysis needs new technology having a reactor structure of a small volume, the reactor can utilize

the dielectric heat from the operation of AC more effectively, without disturbing the flow of gas.

SUMMARY OF THE INVENTION

Therefore, in order to solve the problems involved in the prior art, it is an object of the present invention to provide a reactor for processing hazardous gas using non-thermal plasma and dielectric heat, by which the pressure loss and the clogging can be prevented.

It is other object of the present invention to provide a reactor for processing hazardous gas, by which a lot of gas in a small space can be decomposed.

It is anther object of the present invention to provide a reactor for processing hazardous gas, by which the heat produced from the plasma is concentrated onto a narrow space, so that a catalyst coated on an electrode surface is effectively activated by the heat, thereby reducing its operating power.

It is still another object of the present invention to provide a reactor for processing hazardous gas capable of preventing by-product of a liquid or solid state from being produced.

It is further still object of the present invention to provide a method for processing hazardous gas using the above reactor.

The present invention relates to a reactor and a method for processing a hazardous gas using a non-thermal plasma and a catalyst at same time, the hazardous gas comprising volatile organic compounds, perfluoro-compounds, chlorofluorocarbons, trichloroethylene, dioxin, and nitrogen oxide, wherein the catalyst and the electric heat which is not used in the prior art non-thermal plasma reactor are effectively employed, thereby decreasing the power needed for the operator, and suppressing the production of the by-product of particles or liquid.

In order to achieve the above objects, according to one aspect of the present invention, there is provided a reactor for processing hazardous gas using non-thermal plasma and dielectric heat produced when the non-thermal plasma is produced, the reactor comprising: a body having an inlet and an outlet; a plurality of planar electrodes arranged parallel in the body and spaced apart from each other at a certain interval, in which the plurality of planar electrodes are alternately connected to an alternating current power, and a ground such that every other planar electrode is connected to the alternating current power and the remaining planar electrodes are

connected to the ground; and a power supply unit for applying a voltage of an alternating current frequency to the planar electrodes.

Each planar electrode includes two dielectric plates, one side of the dielectric plate is coated with a metallic thin film and the other side is coated with a catalyst. The two dielectric plates are adhered in such a manner that the metallic thin film of one dielectric plate faces to the metallic thin film of the other dielectric plate.

Preferably, the dielectric plate has a thickness of 0.1 to 2 mm, and is made of one among ceramic, glass, and quartz.

The catalyst is any one selected from a metallic catalyst group containing Pt, Pd, V, and Rh, a zeolite catalyst group containing MS 5A and MS 3A, and a photo catalyst group containing TiO_2.

The power supplied to the planar electrode by the power supply unit is an alternating current voltage of 1 kV to 30 kV at a frequency of 50 Hz to 100 kHz.

According to another aspect of the present invention, there is provided a method for processing hazardous gas using the reactor, the method comprising: installing a plurality of planar electrodes parallel in a reactor, each of planar electrode comprising two dielectric plates, each of the dielectric plates including a catalyst layer coated on an outer surface thereof, and the plurality of planar electrodes being alternately connected to an alternating current power and a ground; applying an alternating current voltage of an alternating current frequency to the planar electrodes to produce a non-thermal plasma and a dielectric heat; supplying the hazardous gas into the reactor; and carrying out a plasma reaction and a catalysis reaction on the hazardous gas to cause a decomposition of the hazardous gas.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objects, other features and advantages of the present invention will become more apparent by the preferred embodiment described with reference to the accompanying drawings, in which:

Fig. 1 is a perspective view illustrating the construction of a reactor for processing hazardous gas using non-thermal plasma according to a preferred embodiment of the present invention;

Fig. 2 is a perspective view illustrating the arranging state of a planar electrode of a reactor shown in Fig. 1;

Fig. 3 is a view illustrating the construction of a planar electrode in Fig. 2.; and

Fig. 4 is a graph showing the efficiency of non-thermal plasma and a catalyst used for a reactor according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Now, a reactor for processing hazardous gas using non-thermal plasma and dielectric heat according to the present invention and an apparatus for processing the hazardous gas using the reactor will be described in detail with reference to accompanying drawings.

Referring Figs. 1 and 2, the reactor for processing hazardous gas using non-thermal plasma and dielectric heat according to the present invention comprises a cubic body 10 with a desired space therein. The body is provided on its front with a flow distributor 14 having an inlet 12 for injecting the hazardous gas into the body. The body also includes an outlet (not shown).

In particular, the body 10 includes two or more planar electrodes 16. Preferably, each electrode 16 has a cubic shape. The planar electrode 16 includes two dielectric plates 18 made of a material such as ceramic, glass, or quartz, these materials having both electrically insulating property and dielectric property. Each dielectric plate 18 may have a thickness of 0.1 to 2 mm. In addition, a dimension of each dielectric plate 18 may be determined depending upon the whole capacity of the reactor, so its length and width may be selected from a few mm to several hundreds mm.

Preferably, each dielectric plate 18 has one side applied with a metallic coating or metallic thin film 20 to conduct electricity, and the other side applied with catalyst or an adsorbent 22.

Each planar electrode 16 is made by closely contacting two dielectric plates 18. Specifically, one side of one dielectric plate 18, on which the metallic thin film 20 is applied, is adhered to one side of the other dielectric plate 18, on which the metallic thin film 20 is applied, so that one planar electrode 16 is formed.

Alternatively, the planar electrode may be formed by interposing a metallic thin film between two dielectric plates. At that time, it is unnecessary to apply the metallic thin film on the adhered surface of each dielectric plate.

The planar electrodes 16 formed by the above process are arranged in parallel in the body of the reactor, as shown in Fig. 2. In the accompanying figure, while only seven planar electrodes are shown, the number of the planar electrodes may be

optionally set depending upon the performance or volume of the reactor. One is connected to an AC supply 24, while the other is connected a ground 26. Preferably, a distance between two adjacent planar electrodes is about 1 to 6 mm. In addition, the planar electrode 16 may be arranged in parallel in several tens or hundreds pairs depending upon the performance of the reactor or a flow rate of the gas to be processed. Preferably, the body forming an outside part of the reactor may be made of ceramic, so that the body can stand the high temperature, as well as having an electrically insulating property.

A power supply unit 28 connected to each planar electrode 16 of the reactor supplies an alternating current of 5 to 20 kV at a specific frequency of several tens Hz or several hundred thousands Hz. Preferably, an inductance and a charging circuit (not shown) may be provided between the power supply unit and the reactor, in order to achieve the impedance matching between the power supply unit and the reactor.

In addition, the catalyst coated on the dielectric plate may be one or more selected from metal catalysts containing Ni, Cu, Co or the like, as well as noble catalysts containing Pt, Rd, Pd or the like, which are known to cause the catalyst to be activated due to the heat. In order to increase a contact surface area between the metallic catalyst and a reacting gas, after a smooth ceramic planar plate of the dielectric plate 18 is applied with γ -alumina, silica, or zeolite, the metallic catalyst may be coated thereon.

In addition, the adsorbent may be γ -alumina or zeolite. Preferably, the zeolite is molecular sieve 3A or 5A. The superior performance may be achieved by using a catalyst substituted with alkali earth metal on such molecular sieve.

With the construction as described above, if the power supply unit 28 supplies a power to the reactor, an electric discharge is happened between the planar electrodes 16, thereby producing electrons and ions. The produced electrons decompose directly a gas molecule to be processed, or are oxidized or deoxidized by O, OH, HO_2, N radical or ion produced due to the collision between electrons and air or added gas molecules which are supplied together with hazardous gas to be processed. The above reacting process is the principle of the typical non-thermal plasma.

The reactor according to the present invention raises the temperature therein using the dielectric heat to easily achieve the desired reaction, and may achieve a

combined effect of the non-thermal plasma reaction and the catalysis reaction by activating the catalyst using the heat generated by the dielectric heat in the reactor. In particular, the combined effect of the non-thermal plasma reaction and the catalysis reaction has an advantage as follows, in relative to the prior non-thermal plasma reaction or catalysis reaction.

While the prior process has to heat the catalyst above a specific temperature in case of oxidizing the hazardous gas using the catalyst, the present invention using both non-thermal plasma reaction and catalysis reaction lowers the temperature, at which the catalyst is activated, so that the process can be performed at a lower temperature. The reason is that the hazardous gas or an oxidizing agent (for example, oxygen, moisture or additive) is changed into a state, of which is easily reacted in the space of the non-thermal plasma.

In addition, while there is not much possibility of a specific reaction which is selectively happened in the prior non-thermal plasma reaction, the selectivity of reaction may be increased by using the catalyst together with the non-thermal plasma. Specifically, in case of removing toluene using the non-thermal plasma reaction only, half or more of toluene is polymerized and is transformed into an aerosol form. Such material is attached to the surface of the electrode, thereby interrupting the drive of the reactor or causing the clogging phenomenon of the reactor. In case of using the catalyst activated by the dielectric heat, the reaction product is easily oxidized, finally converted into carbon dioxide and water.

The operation and working effects of the present invention will now be described.

Example 1

A dimension of the planar electrode 16 is 76 mm x 76 mm x 1 mm, a dimension of the inner metallic thin film 20 is 60 mm x 60 mm x 0.1 mm, the number of the planar electrodes 16 is 15 and a distance between two adjacent planar electrodes 16 is 2 mm. Between two adjacent planar electrodes 16, a reacting space is formed. The reactor is applied with an alternating current of voltage 11 kV and frequency 60 Hz, to produce the non-thermal plasma. At that time, although the power supply was continued during 5 to 6 hours, and the above process was repeated by 10 times, there was no found serious damage due to the insulating destruction in the reactor. Meanwhile, the dielectric plate 18 of the planar electrode

16 may be one selected from a α -alumina plate, a α -alumina plate with γ -alumina and platinum coated, a α -alumina plate with zeolite coated, a quartz plate or the like.

Example 2

When an air was injected into the reactor constructed as described in Example 1, and the reactor was applied with the frequency increased from 60 Hz to 10kHz, the power was increased in relative to the applied frequency, such that the temperature in the reactor and the temperature of the air discharged from a rear end of the reactor were increased. Meanwhile, while the actual surface area of the electrode on which the non-thermal plasma is produced in the reactor is 6 cm x 6 cm x 14 x 2 = 1008 cm^2, the surface area contacted with the exterior is 6 cm x 6 cm x 6 = 216 cm^2. In other words, since the surface area contacted with the exterior, by which a heat loss may be produced, is significantly reduced in relative to the surface area of the electrode, by which the dielectric heat is produced, the produced heat may be effectively used in the reacting process. By contrast, according to a conventional reactor of a tube shape, because the contacted surface area is similar to the surface area of the electrode, a lot of heat loss is happened, and so the heat needed to the reaction is not effectively used.

Example 3

When an air was injected into the reactor constructed as described in Example 1, the pressure loss at each front end and a rear end of the reactor was significantly reduced in relative to that of the conventional reactor of a tube shape, in which the reactor is filled with beads or pellets and the air flows in the reactor. Accordingly, the reactor according to the present invention may be used in a process of high flow rate, and if particles are generated at the reacting process, there is no clogging phenomenon in the reactor.

Specifically, in case that the air containing toluene of several tens ppm to several hundreds ppm is supplied into the reactor and is processed for a long time, a portion of toluene is not oxidized, but is transformed into carbon compounds of particles, thereby adhering to the electrode. The adhered by-product causes the electric property of the electrode to be changed and provides a problem of power

supply. However, according to the present invention, if the platinum catalyst inducing the oxidation reaction is coated on the electrode plate, the production of the by-product of particles or liquid is significantly reduced, and after a certain period, the adhered carbon compounds can be removed by injecting the air only.

Comparative Example 1

In order to examine the influence of the catalyst and the heat on the decomposing performance of the hazardous gas, toluene of 300 ppm as the hazardous gas is supplied to the reactor together with the air, and immediately, the alternating current of 11 kV is applied to the reactor at a frequency of 60 Hz. At that time, the concentration of the toluene discharged from the rear end of the reactor is measured. For the clarity of comparison, the planar electrodes are used as following; 1) the planar electrode of a α -alumina plate, 2) the planar electrode of a α -alumina plate with γ -alumina coated, and 3) the planar electrode of a α -alumina plate with γ -alumina and platinum coated. In addition, in order to examine the effect of the increased temperature at the oxidization of volatile organic compound such as toluene, an operating temperature (a temperature of the air supplied to the reactor and the environment) of each electrode is set to a room temperature, 60 °C and 100 °C.

The results obtained from the above experiment are shown as a graph in Fig. 4. According to the graph, even though the power supply unit consumes same power, the decomposing rate (the decomposed concentration relative to an initial concentration) of the toluene is increased in order of the planar electrodes of α -alumina, γ -alumina, and a platinum catalyst. Meanwhile, in case that the operating temperature is increased in each case, the decomposing rate of the toluene is increased, thereby affirmatively affecting the increased temperature on the reacting process.

Comparative Example 2

In the experiment that the reactor according to the present invention decomposes NF_3 and CF_4 as the hazardous gas, these components belonging to PFC, the decomposing rate is also increased in proportion to the increased temperature in the reactor, as the above case of toluene. In particular, because NF_3

is merely decomposed by the heat if the temperature in the reactor is above 400 °C, the increase of the decomposing rate by the reactor is observed, without using the catalysis.

Meanwhile, because CF_4 can be decomposed at a temperature of above 1200 °C to 1800 °C, there needs an electrode with platinum catalyst coated. In case of using the platinum catalyst, when the non-thermal plasma is produced while the temperature in the reactor is maintained in a level of 300 °C to 400 °C, CF_4 begins to be decomposed.

In addition, in case of decomposing the organic compound such as trichloroethylene (TCE) containing Cl, the increased temperature causes the oxidizing reaction of the hazardous compound to be accelerated. Therefore, the technology of increasing the reacting temperature according to the present invention may be employed to decompose the inorganic compound such as dioxin, PFC, CFC and nitric oxide, as well as VOC such as toluene.

As described above, according to the reactor and method for processing the hazardous gas using the non-thermal plasma and the dielectric heat according to the present invention, the dielectric heat produced when the non-thermal plasma is produced by the AC power supply and the dielectric electrode may be used together with the catalyst in the reacting process, thereby improving the reacting efficiency.

In addition, the pressure loss is reduced in the reactor, and the maintenance of the reactor is easy, and the volume of the reactor is small.

Although a preferred embodiment has been described, many modifications and variations may be made thereto in the light of the above teachings. It is therefore may be practiced otherwise than as specifically described.